

## Science, Technology, Engineering, and Mathematics (STEM) Education

**Dorinda J. Gallant, Ph.D.**  
*School of Educational Policy and Leadership  
College of Education and Human Ecology  
The Ohio State University*

The Soviet Union's launch of Sputnik in 1957 set in motion the United States developing science curriculum and initiatives to make sure a pipeline of scientists was in place to advance its scientific efforts and increase its sustainability as a global leader. Over 50 years later, there is still a thrust to improve science, technology, engineering, and mathematics (STEM) education and to recruit individuals in the STEM field. The National Science Board (2007) has provided several recommendations aimed at addressing the critical needs of the U.S. STEM education system. Recommendations included the legislative creation of an independent, non-Federal STEM council to coordinate and facilitate STEM programs and initiatives; the creation of a standing committee on STEM education within the National Science and Technology Council to coordinate all Federal STEM education programs; the creation of an Assistant Secretary of Education position by the Department of Education to coordinate its efforts in STEM education with stakeholders outside the Department; and a call for the National Science Foundation to lead national efforts to improve pre-kindergarten to college and beyond STEM education. Other recommendations included encouraging all stakeholders to promote horizontal coordination of STEM education among states; encouraging all stakeholders to promote vertical alignment of STEM education across grade levels; and providing strategies for increasing the number of well-prepared and effective STEM teachers. In 2009, the STEM Education Coordination Act of 2009 was passed. The act fulfilled the National Science Board's recommendation to establish a committee under the National Science and Technology Council to coordinate STEM education activities and programs of all Federal agencies.

The National Governors Association's (NGA; 2007) *Innovation America: Building a Science, Technology, Engineering, and Math [STEM] Agenda*, describes STEM-based instruction as follows:

"STEM literacy is an interdisciplinary area of study that *bridges* the four areas of science, technology, engineering, and mathematics. STEM literacy does not simply mean achieving literacy in these four strands or silos. Consequently, a STEM classroom shifts students away from learning discrete bits and pieces of phenomenon and rote procedures and toward investigating and questioning the interrelated facets of the world."

This paper describes STEM education in the United States. First, characteristics of STEM education are described. Then, strategies that have been used in secondary education and post secondary education to motivate and spark students' interest in STEM careers are presented. Finally, the student characteristics found to be related to selecting STEM majors are described.

## Characteristics of STEM Education

Morrison (2006) described several characteristics of STEM education for students, schools, and classrooms. The STEM educated student is a problem solver, logical thinker, technologically literate, and able to relate his (or her) own culture to the learning. The STEM school has STEM literacy as a priority and culturally relevant to all students, has curriculum materials in support of the STEM instruction, fosters a culture of questioning and creativity, and encourages assessment practices that are both formative and performance based. The STEM classroom, grades 6 through 12, is active and student-centered, has computers with STEM software, has easily reconfigurable furniture, and serves students with various learning styles as well as those with disabilities.

## Motivating Students' Interest in STEM

The technological age of video games and instant messaging has created a culture of students accustomed to continuous external stimuli and active engagement within the environment. Hence, the traditional delivery system for mathematics and science instruction (i.e., lecture) in elementary and secondary schools is obsolete in a technological era and fails to capture students' interest. Although many classrooms are beginning to reflect the instant demand for information and the necessity to include technology in instruction with the installation of SMART boards, fiscal constraints, and lack of continuous professional development opportunities on technology creates barriers to adequately preparing students for STEM careers.

Experiential learning, hands-on activities, integrating STEM education, and creating learning communities are possible ways to spark students' interest in STEM and STEM careers. Christie (2008) described several hands-on STEM experience synthesized in state policies by Kyle Zinth, a policy analyst with Education Commission of the States. Real-life and hands-on experiences that have the potential to increase students' interest in STEM and STEM careers include mentoring, internships, afterschool programs that focus on STEM subjects or health, and participation in math and science competitions. Other experiences, such as STEM summer camps (Ivey & Quam, 2009), online games such as CSI: The Experience Web Adventures (Miller, Chang, & Hoyt, 2010), interactive videos and software (Demski, 2009), and STEM library resources (Barack, 2009) also have the potential to stimulate students' interest in STEM and STEM careers.

Providing instruction in which there is curricular connections facilitates understanding of concepts. Integrative STEM education has the potential of bridging students' understanding across STEM disciplines and other subject matter and increasing students' interest in STEM and STEM careers. Integrative STEM education is described as "approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (Sanders, 2008, p. 21). Furthermore, integrative STEM education is grounded in constructivism and findings of decades of cognitive science (Sanders, 2008).

Students involved in working together in cooperative groups on real-world problems are more engaged and interested in STEM subject matter. In research by Fortus et al., they found that because students were presented authentic problems their interest levels in science, technology, engineering, and mathematics increased because students saw the need for, or value in, that information.

Integrating STEM education through project-based activities has the potential of increasing the quality of learning and enhancing motivation. Freeman, Alston, and Winborne (2008) investigated undergraduate students' attitudes, motivation, and learning in STEM as a result of participating in linked (or integrated) courses at two historically Black colleges and universities in 2006 and 2007. The authors found that the majority of students (at least 90% both years) indicated that they would recommend linked classes to others. At one of the institutions, the success rate (i.e., course grades of A, B, or C) of students in clustered courses was higher (61% in precalculus and 75% in general biology) than students in non-clustered courses. Although students indicated that they would recommend the linked courses to others and a higher success rate was reported in the academic performance of clustered students at one institution, students at both institutions did not feel that the linked courses helped them better understand course material. Furthermore, students at both institutions provided, on average, a neutral response to linked courses increasing their interest in attending graduate school or in pursuing a career in math or science. Positive levels of motivation in the core STEM linked courses were found for both institutions. However, overall, no significant differences were found between pre- and post-measures of motivation except for higher post-test intrinsic motivation of students at one of the institutions. The authors further asserted that classes that adopted a learning community approach enhanced students' attitudes and motivation toward science and mathematics.

Exploring STEM career options through collaborative high school seminars also has the potential to spark students' interest in STEM and STEM careers. Cantrell and Ewing-Taylor (2009) reported on the effectiveness of an outreach program that attracted high school juniors and seniors to a seminar series (K-12 Engineering Education Program [KEEP] Seminar Series) designed to expose students to career possibilities in STEM fields. Students were recruited and met weekly for eight weeks. At the end of each session, students completed surveys. The authors found that across the eight weeks over half of seminar participants made weekly changes in their career choice, and the majority of the changes were related to the career of the presenter on the evening the change occurred. In addition, female

participants and seniors were more stable in their career choices (i.e., changed career choices less frequently). By the end of the seminar series, engineering and medical careers gained the greatest number of students, science careers lost the greatest number of students, and computer science and undecided careers remained fairly constant. Most students (over 90%) reported that the seminar series increased their career knowledge base. Seniors' seminar experience was reported to be more meaningful to their current needs (e.g., make connections between seminar topics and high school courses). Moreover, sessions that received low ratings were lectures with little or no student interaction. The authors posit that providing students with explicit experiences that contribute to and help to operationalize their career knowledge is important to students making information-based career decisions.

## Predictors of STEM Participation

Identifying possible variables that contribute to students' inclination toward STEM careers is important for the sustainability of STEM fields. Identified variables can potentially serve as initial criteria for recruitment of students to STEM careers. Nicholls, Wolfe, Besterfield-Sacre, Shuman, and Larpkattaworn (2007), using incoming freshmen data from the Cooperative Institution Research Program for two universities, tested a methodology for identifying variables that consistently showed significant differences between students intending to major in STEM subjects versus non-STEM subjects. The authors asserted that "variables that consistently show significant differences across numerous subgroups are valued more highly than variables that are significant for only two subgroups" (p. 36). The authors found quantitative measures of academic ability and qualitative measures of interests, attitudes, and personal characteristics provided the best predictors of students pursuing majors in STEM subjects. High SAT mathematics scores, high school grade point average and, to a lesser degree, SAT verbal scores were quantitative indicators of STEM interest while self-ratings of mathematical ability, computer skills, and academic ability were qualitative indicators of a STEM orientation. In general, students oriented toward majors in STEM subjects tended to spend more time studying, wanted to make theoretical contributions to the science field, had fewer focused personal goals, and were stable in their choice of major or career compared to students oriented toward majors in non-STEM subjects.

Wai, Lubinski, and Benbow (2009) explored spatial ability as an indicator for identifying high-school students who pursue STEM careers. Using a longitudinal database, the authors sort to (a) determine the consistency of spatial ability in predicting educational and occupational outcomes on STEM domains, (b) determine the extent to which early signs of exceptional spatial ability indicated the development of STEM expertise, and (c) demonstrate how neglecting spatial ability leads to talented students not being identified for STEM domains. Several findings related to the study's objective emerged. First, spatial ability was the main psychological attribute among students who later achieve advanced educational and occupational STEM credentials. Second, spatial ability was critical in the structuring educational and occupational outcomes in both the general population and among

intellectually talented students. Finally, talent searches that restricted selection criteria to mathematical and verbal ability measures overlooked many intellectually talented students.

## Designing an Integrated STEM Curriculum for Middle School

Satchwell and Loepp (2002) discussed the issues associated with the design, development, and implementation of a standards-based, integrated mathematics, science, and technology curriculum, IMaST, for students in grades 6 through 8. In addition to integrating mathematics, science, and technology, the IMaST curriculum also include connections to language arts, social studies, and readings that highlight careers related to the curriculum content. Challenges to developing and implementing an integrated curriculum include (a) the complexity of developing an integrated course consisting of three disciplines, with three separate sets of standards; (b) creating a common planning time for teachers to work together; (c) scheduling; (d) classroom space; (e) teachers' classroom management skills; and (f) teachers' ability to transition to constructivist pedagogy. The benefits of developing and implementing an integrated curriculum include (a) students are able to connect concepts across discipline, (b) students are more motivated to learn, and (c) students score higher on standardized mathematics and science tests.

## Summary

To maintain an adequately filled and well-prepared scientific workforce for the future, it is important that parents, policy makers, and school personnel understand issues related to motivating students toward STEM and STEM careers, characteristics of individuals in STEM careers, and challenges and benefits to designing and implementing a STEM curriculum. Creating an environment conducive for STEM education has the potential of increasing STEM content knowledge among students and thus increasing students' achievement in mathematics and science. The importance of ongoing professional development for teachers cannot be overemphasized. Teachers who are actively engaged in professional development opportunities that demonstrate integrated STEM education pedagogy have increased STEM content knowledge (Felix & Harris, 2010). It is hoped that teachers can internalize what they have learned and provide students with opportunities to actively engage in STEM.

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